Human Effectiveness Directorate

USAF Scientific Advisory Board 1999 S&T Program Review Knowledge Representation Technologies for Human Performance Enhancement

Air Force Research Laboratory | AFRL
Science and Technology for Tomorrow's Aerospace Force

Dr. Wesley Regian
Warfighter Training Research Division

Challenge

- **Cognitive Engineering on DoD Agenda**
  - **Distributed Mission Training**
  - **Advanced Distributed Learning**
  - **Air Expeditionary Forces**

- **Required Cognitive Technologies on Back Burner**
  - **Effective courseware can be reliably engineered**
  - **Enhanced performance can be reliably engineered**
  - **Distributed performance enhancement imaginable**

CAI and ICAI Effectiveness

Computer Assisted Instruction ***(Instructional Systems Design-based)***

- **Instructional Effect** **0.39 Sigma (65%tile)**
- **Instruct. Efficiency** **24% learning time reduction**
- **Cost Effectiveness** **lowest cost per Sigma gain**

Intelligent Computer Assisted Instruction ***(Cognitive Science-based)***

- **Instructional Effect** **1.00 Sigma (84%tile)**
- **Instruct. Efficiency** **55% learning time reduction**
- **Cost Effectiveness** **Similar to CAI when authored**

The Approach

- **Phase I (Done)**
  - **Instructional Engineering Achieved**
    - **Intelligent Computer Assisted Instruction (ICAI) highly effective**
    - **R&D spins off Knowledge Representation (KR) Technologies**
    - **KR Technologies enable Cognitive Engineering**
- **Phase II (You are Here)**
  - **Practical Knowledge Representation**
    - **Standardized & Streamlined Cognitive (KR) Modeling**
    - **Practical knowledge acquisition & application**
    - **Tools for distributed KR-based agents**
- **Phase III (Stay Tuned)**
  - **Global Performance Engineering**
  - **Warfighter Operations Center Training & Perf. Support**
  - **Integrate into Distributed Mission Training**

Basic Research Foundation
AFOSR 6.1 TRAIN

T.R.A.I.N

Training Research for Automated INstruction

Recognition

- **National**
  - **Federal Lab Consortium Award: Tech Transfer**
  - **VP Gore Hammer Award (1998)**
- **DoD - Reliance center for cognitive science**
- **Air Force**
  - **World-Class Rating by AF SAB**
- **AFOSR**
  - **USAF Basic Science Award (1997)**
  - **STAR Team - TRAIN (FY95-98)**
- **AFRL/HRL**
  - **Scientific Excellence (1990, 1993-95)**

Productivity

- **Since May 1992**
  - **129 experiments**
    - **12,633 subjects**
    - **177,052 hours**
  - **5 books**
    - **52 peer reviewed publications**
    - **115 unreviewed publications**
  - **25+ ICAI systems delivered**
    - **World's largest research base on human performance**
    - **Performance models based on 300,000+ hours of lab & field data**

Basic Research Foundation Team

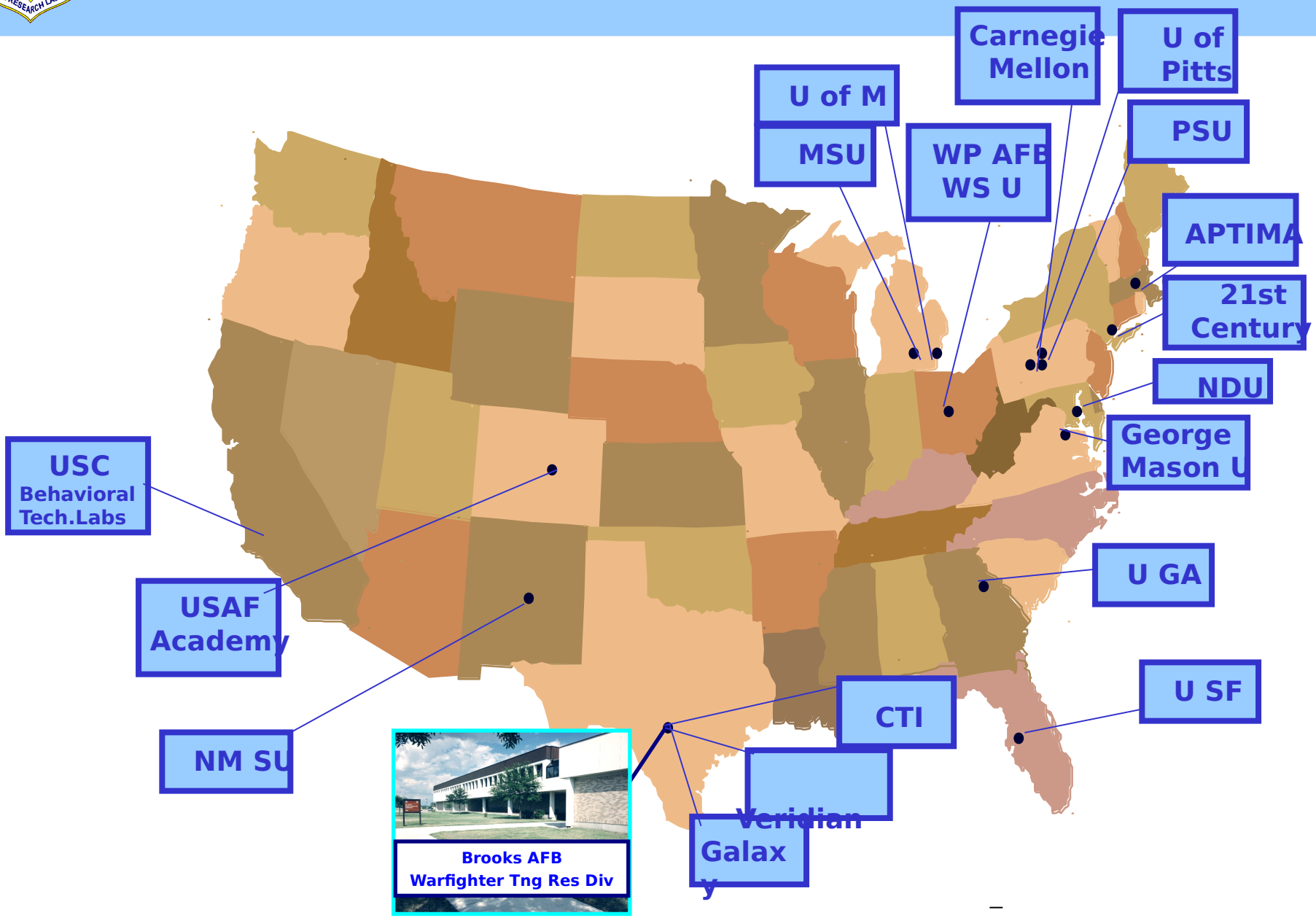
Government

- Regian (PhD - U.Cal / LRDC)
  - Cognitive modeling & model-based pedagogy
- Schiflett (PhD - Texas Tech)
  - Performance modeling & team-based pedagogy
- Goettl (PhD - U.Ill/Clemson)
  - Practice schedules, observational learning
- Ashworth (PhD - Yale)
  - Visual cognition, recognition,discrimination
- Gluck (PhD - CMU)
  - Student modeling, knowledge engineering, ATI

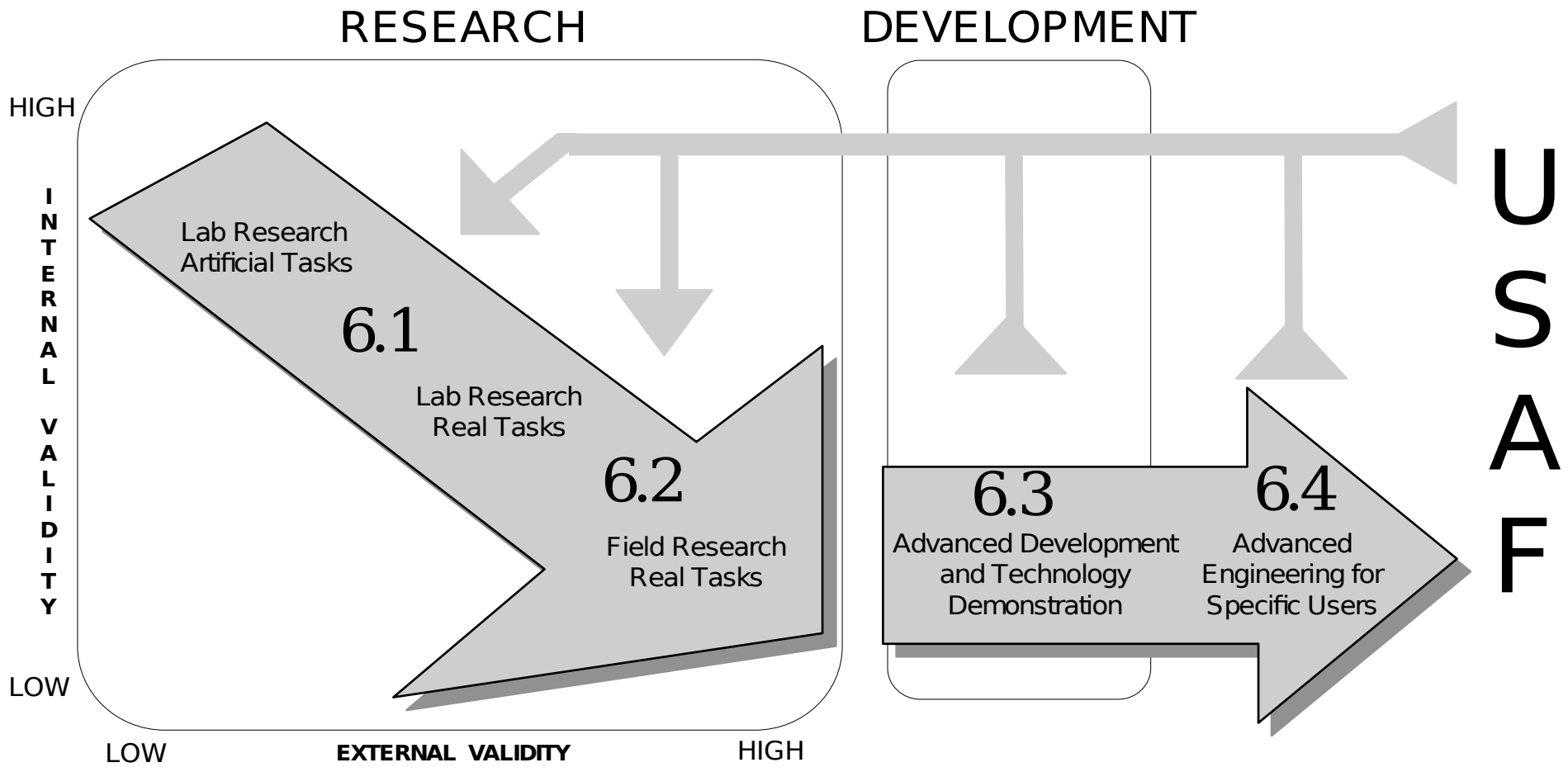
Contract

- Command Technologies
  - Carol Horwitz, MS, Artificial Intelligence
- Galaxy Scientific
  - Kevin Kline, MS, Computer Science
  - Randy Morlen,MS, Computer Science
- Veridian
  - Linda Elliott, PhD, IO Psychology
- Aptima
  - Daniel Serfaty, EE, Organizational Modeling

“Collaborators”



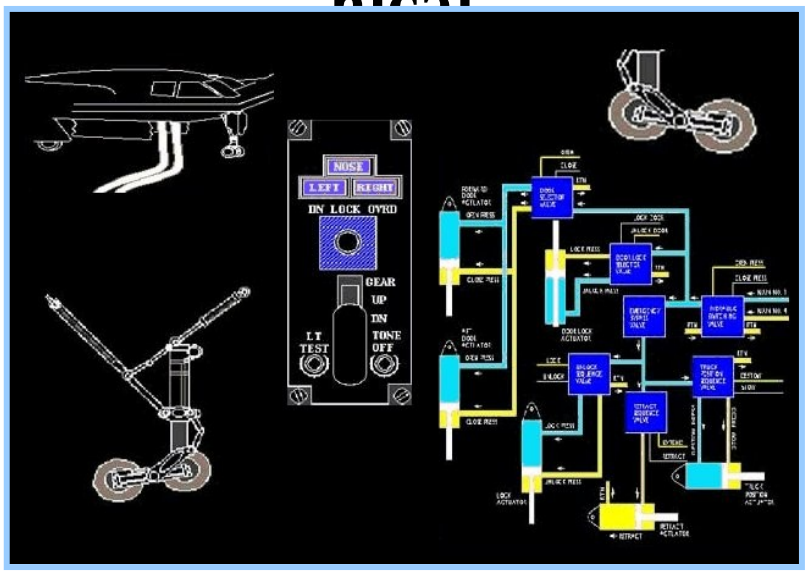
Basic Research Foundation Strategy



SynTeam C3STARS AWACS E3
TRAIN WOC/TPS DMT

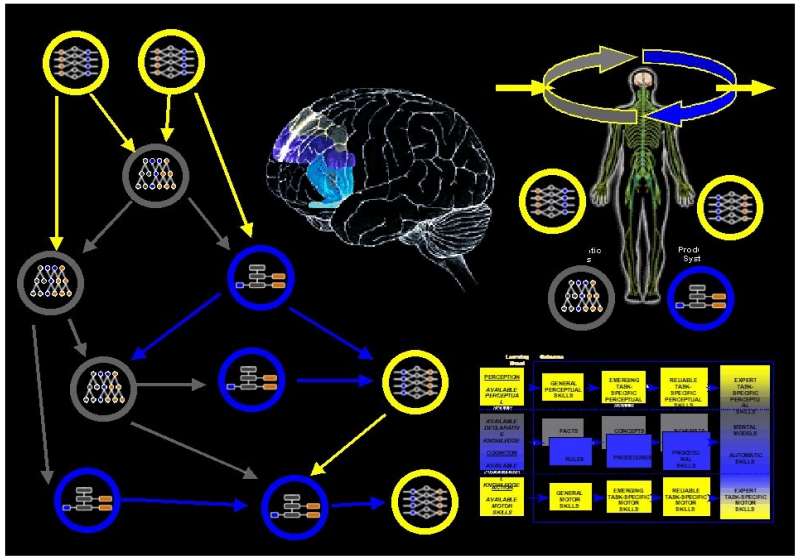
Engineering

Electrical/Mechanical



Formal methods and quantitative models applied to practical ends such as structures, machines, processes, and

Cognitive



Formal methods/models for designing technologies that capitalize on human strengths and

Courseware Effectiveness
Regian & Fletcher 1999

Instructional Setting & Courseware Type		Number of Studies	Effect Size	Outcome Percentile
Elementary School	CAI	28	0.47	68
Secondary School	CAI	42	0.42	66
Higher Education	CAI	101	0.26	60
Adult Education	CAI	24	0.42	66
Military Training	CAI	38	0.40	66
Overall	**CAI**	**233**	**0.39**	**65**
Higher Education	ICAI	1	0.97	83
Military Training	ICAI	1	1.02	84
Secondary School	ICAI	1	1.00	84
Overall	**ICAI**	**3**	**1.00**	**84**

Courseware is decidedly effective in

Courseware Costs and Benefits
Regian and Fletcher 1999

Cheapest way to improve mathematics scores.

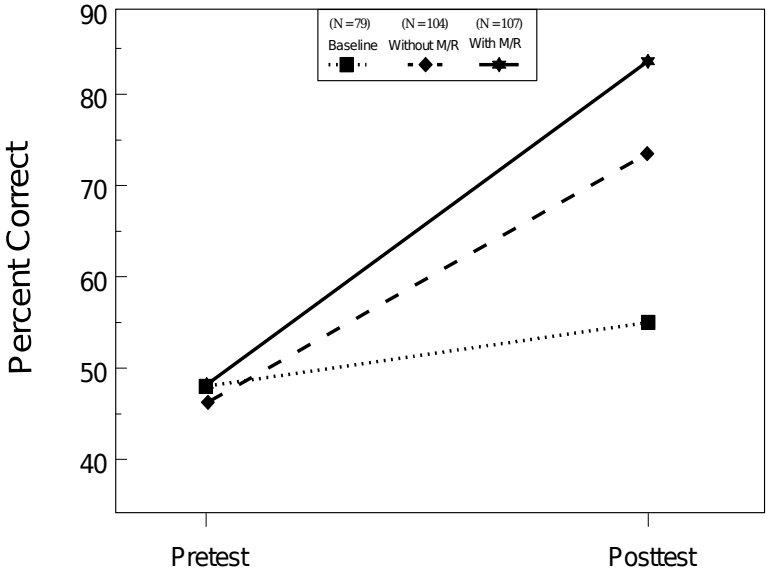
Treatment	Setting	Minutes per Day	Cost per SD Gain
Add Instruction Time	Class	30	2,667
Tutoring by Adults	Private	20	1,612
Reduce Class Size	Class	N/A	1,179
Minicomputer CAI	Lab	N/A	375
Tutoring by Peers	Private	20	286
Microcomputer CAI	Class	N/A	199

Fastest way to reach instructional objectives.

Instructional Setting & Courseware Type	Number of Studies	% Time Reduction
Military Training CAI	23	28
Military Training CAI	N/A	30
Higher Education CAI	17	34
Adult Education CAI	15	24
Overall CAI	**55+**	**29**
Higher Education ICAI	**3**	**55**

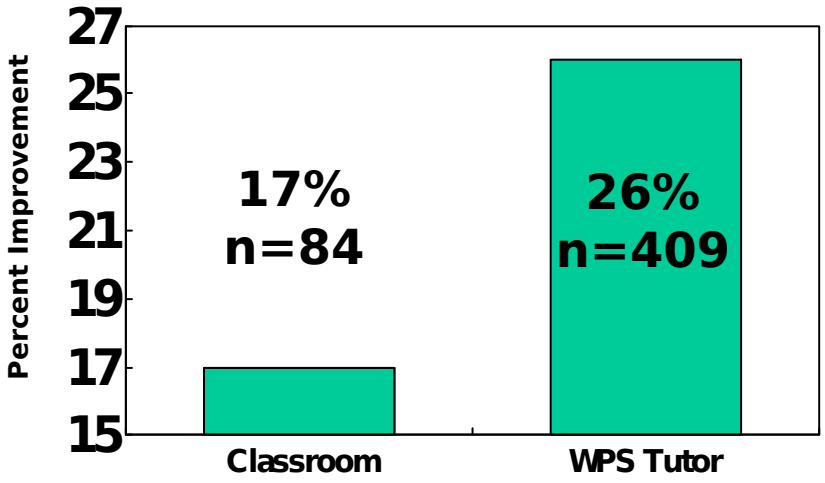
Model-based Instruction
Superior to Curriculum-based (Shute, Regian)

Introductory College Statistics



10% improvement on statistics problem solving performance.

High School Mathematics



One letter grade improvement on word problem solving performance.

Optimized Transfer
At Minimal Expense (Regian)

	VR	CAI
Tour 1	2.1	1.3
Tour 2	1.2	1.2
Tour 3	2.1	1.8
Tour 4	0.5	0.4
Tour 5	1.4	0.8
Average Errors	**1.5**	**1.1**

No difference in building navigation performance after

	VR	CAI
Test 1	1.7	1.0
Test 2	1.1	0.6
Test 3	0.5	0.4
Average Errors	**1.1**	**0.7**
Test 1	65.2	59.1
Test 2	48.0	37.5
Test 3	25.1	29.3
Average Latency	**46.1**	**42.0**

No difference in console operation performance after

Principled Part Task Training via Backward Transfer (Goettl)

Engineering an Old Problem

- Part-task (PTT) training of complex tasks
  - Whole task is dangerous, expensive, or impossible
- Technique to identify critical component tasks
  - Degree of transfer between components and whole task

	Acquisition	Transfer	Backward Transfer
Experimental	Whole Task	Whole Task	Component Tasks
Control	Component Tasks	Whole Task	

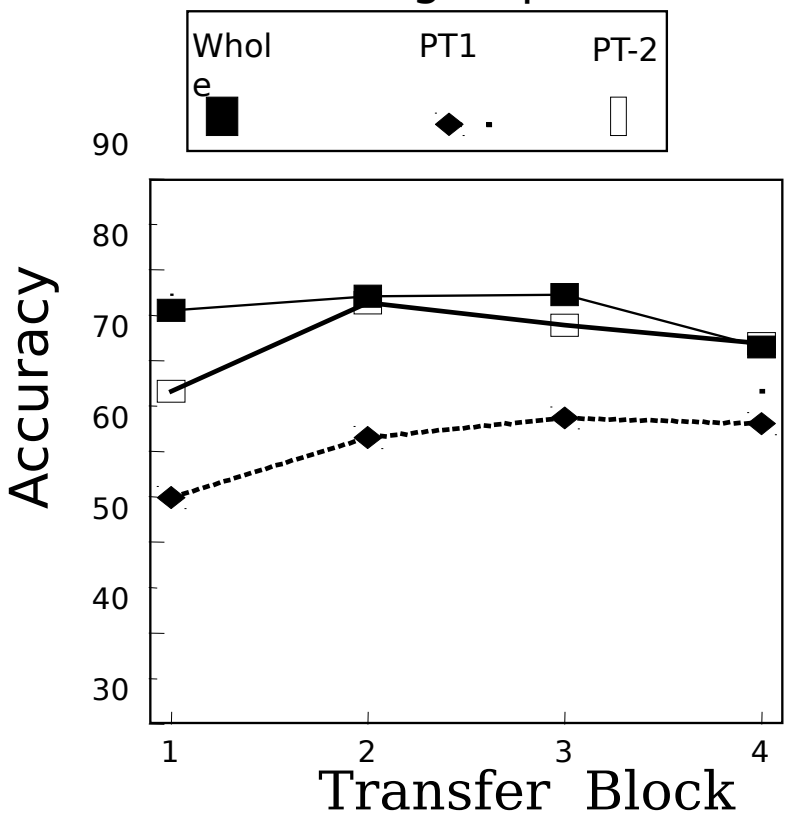
Alternative Design Methods

- Rational Part Task Training
  - Part-tasks based on intuitive decomposition
  - Often less effective than whole task training
- Principled Part Task Training
  - Part-tasks based on empirical decomposition
  - Generate candidate part-tasks rationally
  - Select effective part-tasks empirically

Component Task	Backward Transfer
Gate Aiming	63.12
Sp. Orientation	8.74
Recovery	- 4.84
Heading	- 5.20
Roll	34.61

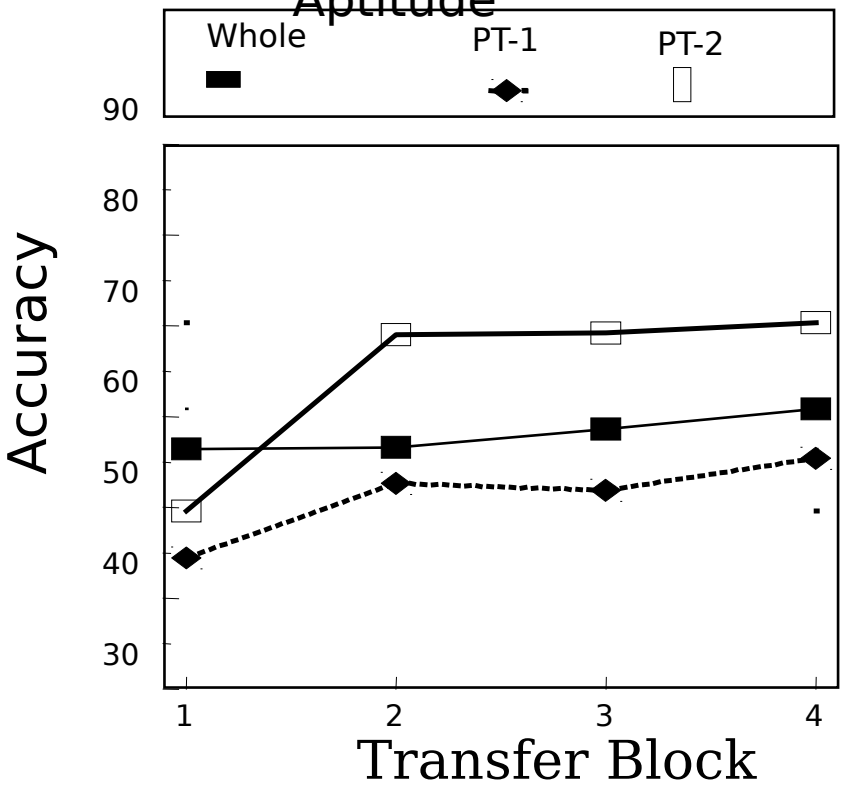
Overcoming Aptitude Deficiencies
Principled Part Task Training (Goettl)

(a) High Aptitude



For students with higher aptitude, Principled PTT is equivalent to Whole Task Training, and significantly better than Rational PTT.

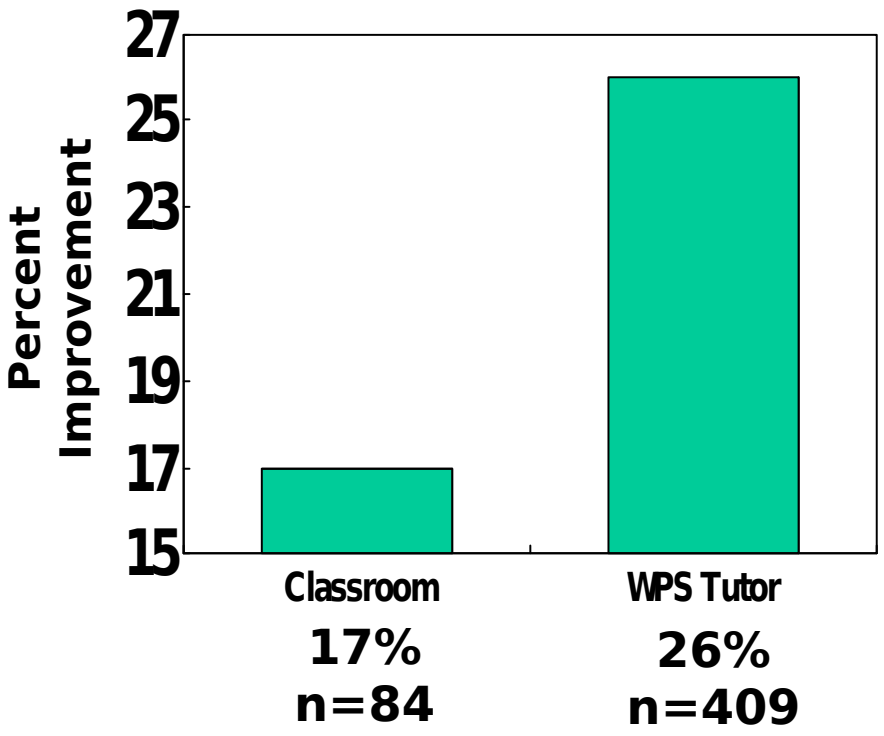
(b) Low Aptitude



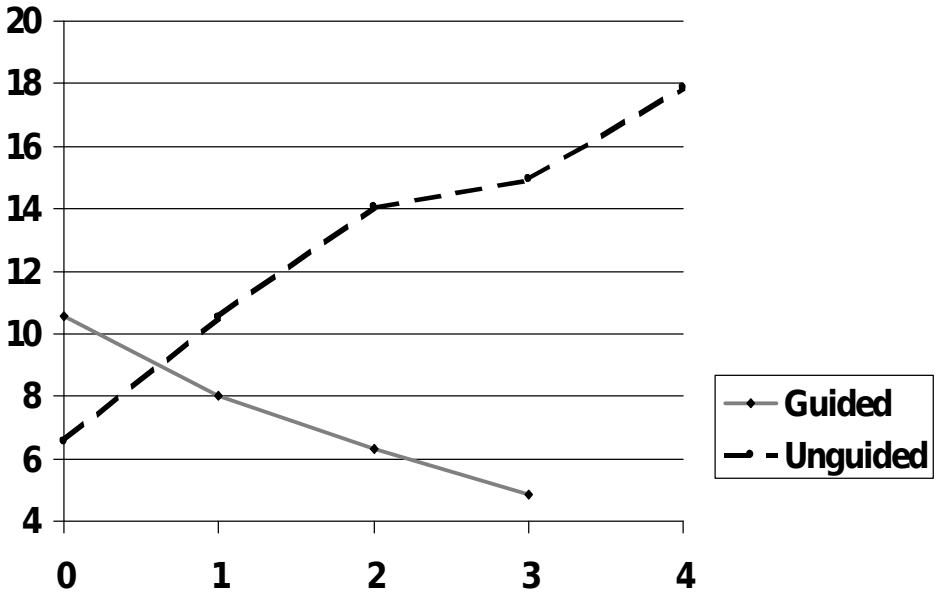
For students with lower aptitude, Principled PTT raises their performance to rival the performance of high aptitude students.

Resolving Aptitude Differences

Guidance When Needed (Regian)



Model-based tutoring produced an overall effect equivalent to one letter grade improvement on word problem solving performance.

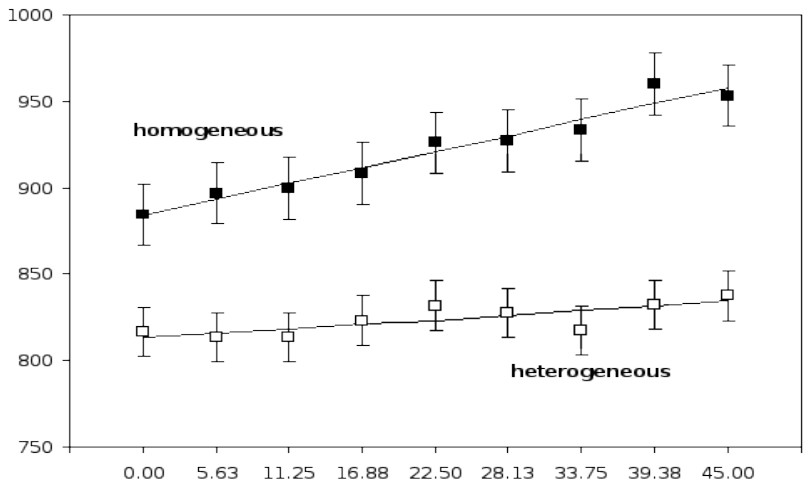


Detailed guidance was better for students with lower aptitude.

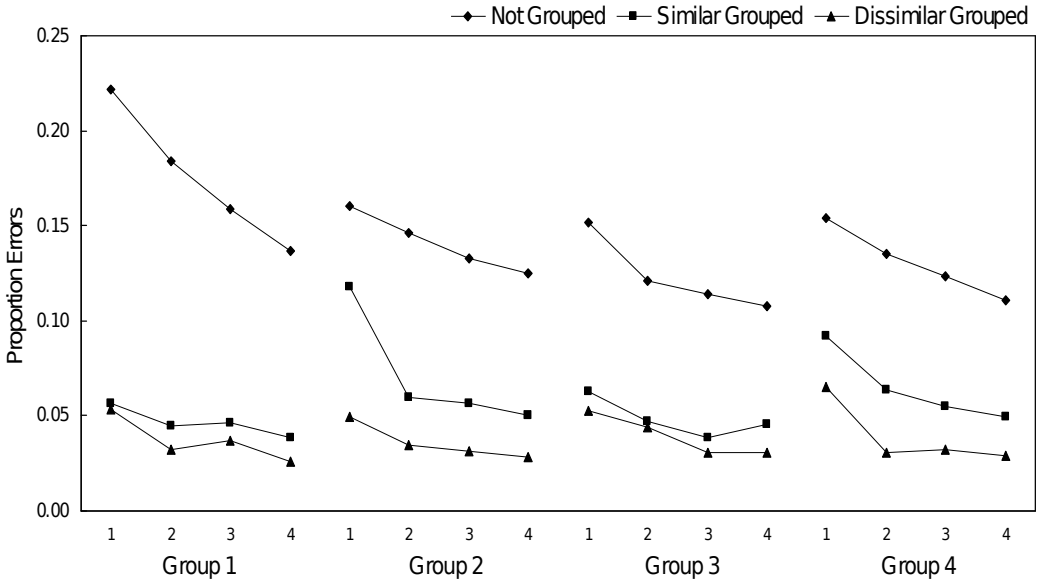
Brief guidance was better for students with higher aptitude.

Enhancing Performance?
Near Transfer (Ashworth)

When learning aircraft identification, homogeneous grouping of stimuli produces slower performance and more errors than heterogeneous grouping.

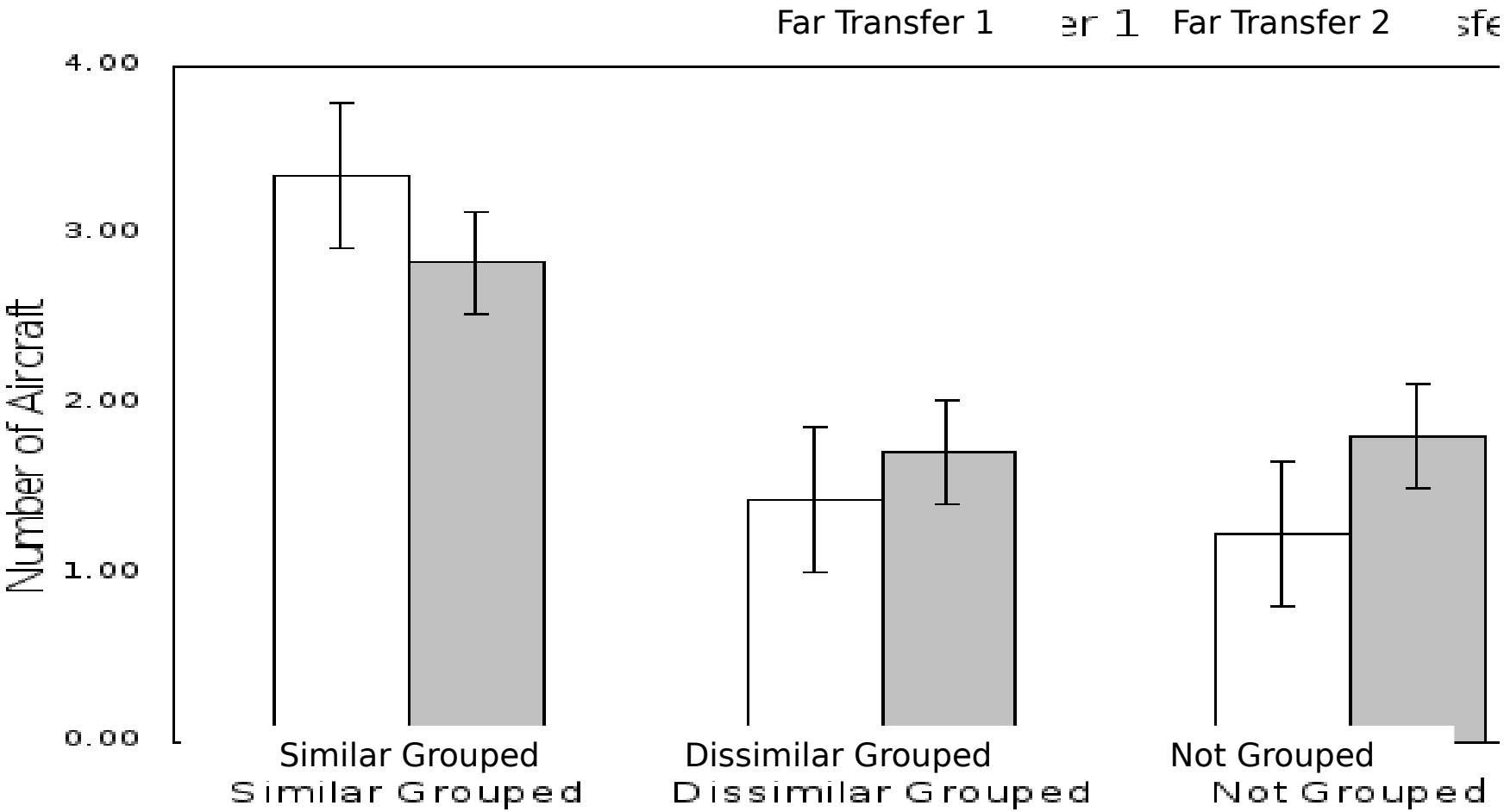


Slower Performance During Learning



Higher Error Rates During Learning

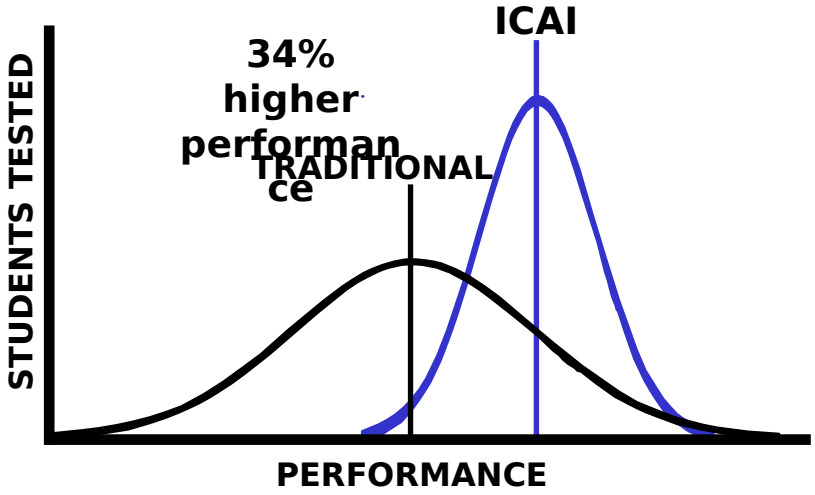
Enhancing Real-World Performance
Far Transfer (Ashworth)

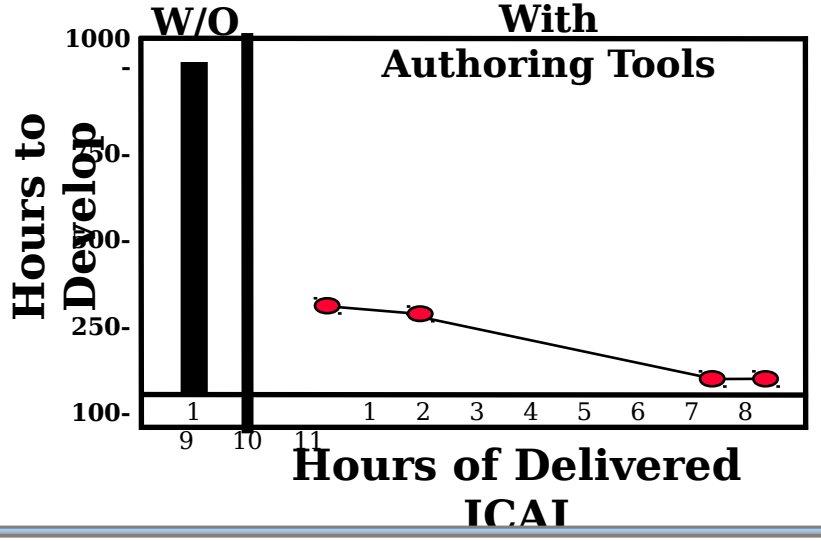


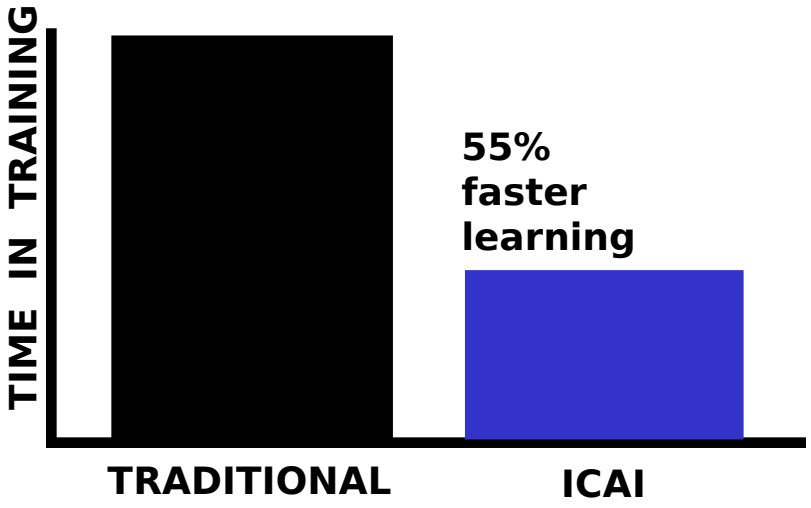
When actually performing aircraft identification, subjects who had studied homogeneously grouped stimuli were faster and more accurate than subjects who had studied heterogeneously grouped stimuli

Cognitively Principled Instruction

Effective but Expensive (Regian)







- ICAI is extremely effective
- Hand-made ICAI is expensive
  - 1000 hours for 1 hour of instruction
- Object oriented tools are helping
  - 250 hours for 1 hour of instruction
  - Productivity now comparable

CAPTOR - Microsoft Internet Explorer

INTRO MENU HELP QUIT PAUSE

JPEC Products References

J1 Personnel
J2 Intelligence
J3 Operations
J4 Logistics
J5 Plans
J6 C4-Systems

Introduction to Crisis Action Planning

Crisis Action Planning (CAP) is **based on current events and conducted in time-sensitive situations and emergencies** using assigned, attached, and allocated forces and resources. Crisis action planners base their plan on the actual circumstances that exist at the time planning occurs. They follow prescribed CAP procedures that parallel deliberate planning, but are more flexible and responsive to changing events.

This section describes **how the basic planning process is adapted and employed to plan and execute joint operations in crisis situations.**

http://38.222.230.158/dtest/

Transition Domains

Domain	CUSTOMER
Joint Suppression of Enemy Air Defense	JSEAD-JTF Nellis AFB
Liver Tutor	Wilford Hall Medical Center (Organ Transplant Ward) Lackland AFB TX
Auxiliary Power Unit Tutor	AETC Aircraft Maintenance School Keesler AFB MS
C-130 Inter Phone Troubleshooting Tutor	AETC Keesler AFB MS
Orbital Elements Tutor	AFSPACECOM, 20th Space Surveillance Sqdn, Peterson AFB CO AETC Undergraduate Space & Missile Training Vandenberg AFB CA
Tactical Orbital Display Console Tutor	AFSPACECOM, 20th Space Surveillance Sqdn, Peterson AFB CO AETC Undergraduate Space & Missile Training Keesler AFB MS
Submarine Refrigeration System Tutor	Mare Island Naval Shipyard California
Aircraft Engine Maintenance Tutor	RAND
The Light-Weight Multi Band Satellite Terminal Tutor	AFMC Electronic Systems Center Air Mobility Command

Domain	CUSTOMER
Crisis Action Planning	OSD/P&R & J7 Pentagon
Air Traffic Control Tutor	AF Special Operations Command Hurlbert Field FL AETC Air Traffic Control School Keesler AFB MS
Missile Launch Control Room Tutor Training	AETC Undergraduate Space & Missile Keesler AFB MS
K-G194 Troubleshooting Tutor	AETC Crypto Maintenance School Lackland AFB TX
Horizontal Situation Indicator Tutor	AETC Tech Trng School Keesler AFB MS
B2 Landing Gear Tutor	Air Combat Command
M-16 Assembly - Disassembly Tutor	AETC Combat Arms School
AN/UGC-141 Teletypewriter	Crypto Tech School Lackland AFB TX
1502B TDR (Time Domain Reflectometer)	Avionics Tech School Keesler AFB MS
AN/ARC-190 High Frequency Radio	Avionics Tech School Keesler AFB MS
Pulse Oximeter	AETC Tech Trng School Sheppard AFB TX

Emerging Solutions

Practical Cognitive Technologies

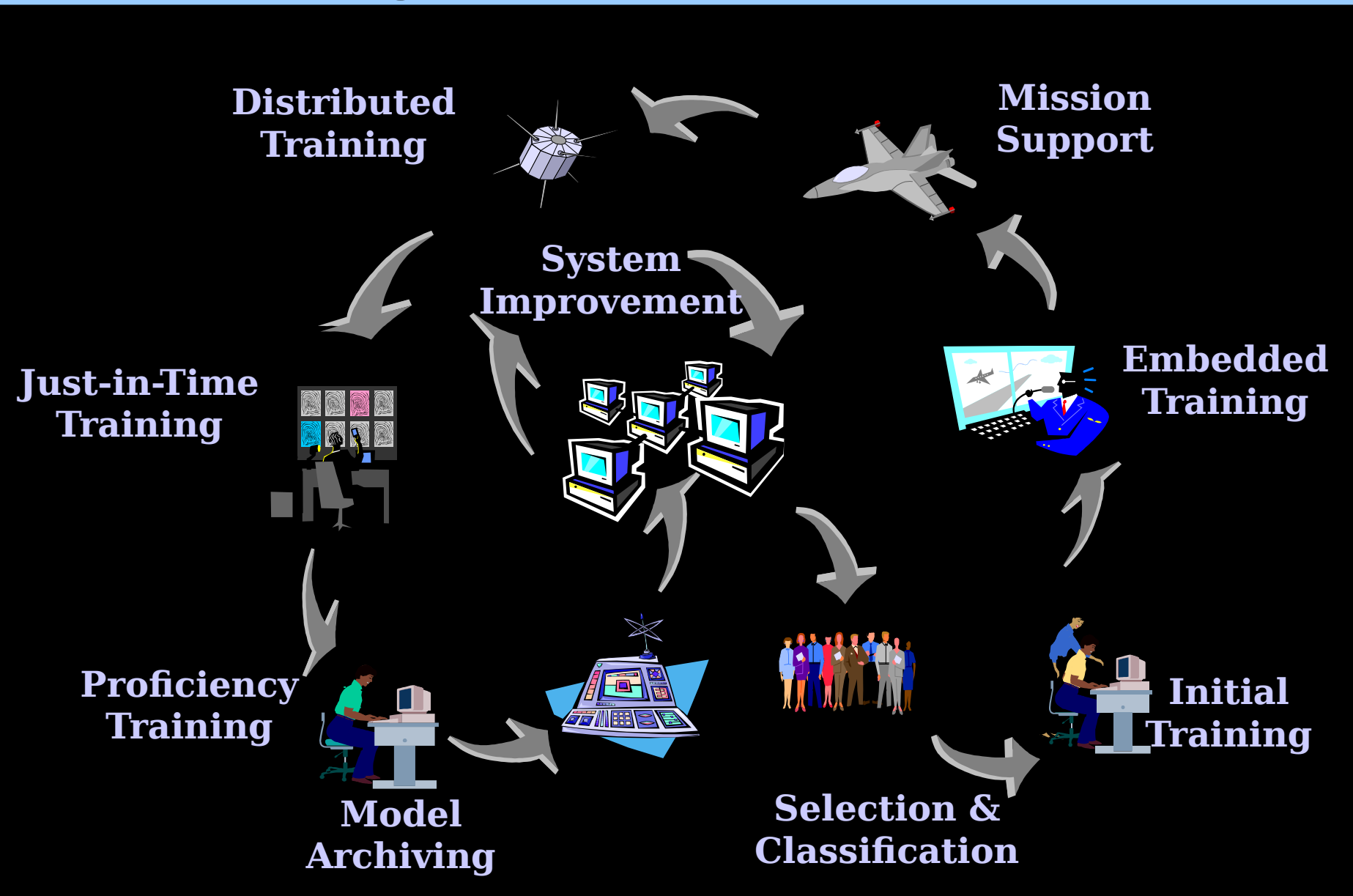
- Standardized knowledge/skills modeling technology
  - **ENGRAMS** - Encoding Normative Grammar for Representing Acquired Memory and Skill
  - **SMART** - Student Modeling Approach for Responsive Tutoring
- Automated extraction of existing, knowledge-bearing data
  - **ROSETTA** - Rational Overlay System for Exploiting Traditional Task Analyses
- Efficient methods for extraction of human expert knowledge
  - **DNA** - Decompose, Network, Assess
- Authoring tools for model-based tutoring, coaching, support
  - **HISIDE** - High-level Simulation with Instructional Design Expertise
  - **VIVIDS** - Virtual Interactive Intelligent Tutoring System Development Shell

Exit Criteria

Practical Cognitive Technologies

- Standardized knowledge/skills modeling technology
  - » Demonstrate utility for diverse ICAI development
- Automated extraction of existing knowledge-bearing data
  - » 50% reduction in time to complete cognitive task analysis
- Efficient methods for extraction of human expert knowledge
  - » 70% reduction in time to develop student models ICAI
- Authoring tools for model-based tutoring, coaching, support
  - » 80% reduction in time to develop ICAI

Next Step: Global Performance Engineering
Warfighter Operations Center Training and Performance Support



Leveraging

Brooks

Mesa